Appendix J: Agriculture and Forestry - detailed policy description/analysis

Overview

The Agriculture and Forestry (AF) sector includes emissions and mitigation opportunities related to use of biomass energy, protection, and enhancement of forest and agricultural carbon sinks, control of agricultural methane emissions, production of renewable fuels, and reduction of transport emissions from imported agricultural commodities. The CCAG recommends a set of 11 policy options for the AF sector that offer the potential for major GHG emissions reductions from the reference projection. As summarized in the table below, these 11 policy recommendations could lead to emissions savings from reference case projections of 5.9 $MMtCO_2e$ per year by 2020 and cumulative savings of 51 $MMtCO_2e$ from 2007 through 2020. The weighted average cost of saved carbon from the policy options for which quantitative estimates of both costs and savings were prepared was -$0.5 per metric ton of CO_2 equivalent.

For each recommended AF policy, this technical appendix provides details on design, analysis, quantification of impacts, and other related information. (See Appendix E for explanation of the general methods applied). GHG reductions associated with biomass energy utilization from biomass supply quantified from options F3a and F3b will overlap with GHG reductions achieved by commercializing biomass gasification/combined cycle technology in option F4 (since the biomass energy from F3a and F3b will serve as input to F4). Therefore, GHG reductions have been quantified under F3a and F3b only.

Agriculture and Forestry Sector Summary of Results						
#	Policy Name	Estimated 2010 GHG Savings ($MMtCO_2e$)	Estimated 2020 GHG Savings ($MMtCO_2e$)	Estimated Costs or Cost Savings Per Ton ($/$tCO_2e$)	Cumulative 2007-2020 GHG Savings ($MMtCO_2e$)	Level of CCAG Support
A-1	Manure Management – Manure Digesters	0.2	0.5	$1	3.8	Unanimous
A-2	Biomass Feedstocks for Electricity or Steam/Direct Heat	0.05	0.1	-$8	4.5	Unanimous
A-3	Ethanol Production and Use	0.5	4.0	$0	28	Unanimous
A-7	Convert Land to Forest or Grassland	Not Quantified	Not Quantified	Not Quantified	Not Quantified	Unanimous
A-8	Reduce Permanent Conversion of Farm and Rangelands to Developed Uses	0.1	0.2	$65	1.6	Unanimous
A-9	Programs to Support Local Farming / Buy Local	0.01	0.02	$6	0.1	Unanimous
F-1	Forestland Protection from Developed Uses	0.3	0.3	$17	3.7	Unanimous
F-2	Reforestation/Restoration of Forestland	0.02	0.1	$44	0.7	Unanimous
F-3a	Forest Ecosystem Management – Residential Lands	0.5	0.5	-$21	6.4	Unanimous
F-3b	Forest Ecosystem Management – Other Lands	0.2	0.2	-$21	2.9	Unanimous

F-4	Improved Commercialization of Biomass Gasification and Combined Cycle	Not quantified[a]	Not quantified[a]	Unanimous

[a] Not quantified due to overlap of biomass energy resource with Option F3a and F3b.

The energy savings (measured in MMcf of natural gas, MWh of electricity, and MMgal of gasoline and diesel, and measured in dollars) associated with AF policy recommendations are presented in the table below.

Option No.	Option Name	2020 Cumulative Energy/Fuel Savings Amount	Units	Cost Savings ($1,000)
F1	Forestland Protection from Developed Uses	not quantified		not quantified
F2	Reforestation/Restoration of Forested Lands	not quantified		not quantified
F3a	Forest Ecosystem Management - Residential Lands	127,112	MMcf Nat.Gas	979,577
F3b	Forest Ecosystem Management - Other Lands	56,836	MMcf Nat.Gas	438,006
F4	Commercialization of Biomass Gasification/Combined Cycle	not quantified		not quantified
A1a	Manure Energy Utilization - Dairies	498,383	MWh Elect.	18,802
A1b	Manure Management - Land Application	not quantified		not quantified
A2	Biomass Feedstocks for Electricity or Steam Production	22,921	MMcf Nat.Gas	149,516
A3	Ethanol Production (high end of estimated benefit)	4,373	MMGal Gasoline	0[a]
A4	Change Livestock Feedstocks	NA		NA
A5	Reduce Nonfarm Fertilizer Use	not quantified		not quantified
A6	Grazing Management	not quantified		not quantified
A7	Convert Agricultural Land to Grassland or Forest	not quantified		not quantified
A8	Reduce Permanent Conversion of Ag & Rangeland to Developed Uses	not quantified		not quantified
A9	Programs to Support Local Farming/Buy Local	15	MMGal Diesel	44,449
Totals				1,630,350

[a] No savings are estimated to the consumer. Retail gasoline-equivalent gallon of ethanol is assumed to be equal to gasoline.

A-1 Manure Management - Manure Digesters

Policy Description:

Reduce CH_4 emissions from livestock manure through the use of manure digesters installed at dairies. Energy from the manure digesters is used to create heat or power, which offsets fossil fuel-based energy production and associated CO_2 and black carbon emissions.

Policy Design:

- **Goal levels:** Manage dairy manure using anaerobic digesters and energy capture technology (e.g., electricity generators) covering 25% of the state-wide dairy population by 2010. Increase this level to 75% of the dairy population by 2020. Because use of manure digesters at beef feedlots are not as far along in development as dairy applications, implement at least three demonstration projects at large beef feedlots (>5,000 head) by 2010. This represents about 5% of the current feedlot population. Expand the use of digesters or other energy production technology at beef feedlots to 50% of the feedlot population by 2020.
- **Timing:** See discussion under goal levels above.
- **Parties:** Arizona Department of Agriculture, universities, Arizona Department of Environmental Quality, industry associations, and dairies.

Implementation Method(s):

Funding Mechanisms – Funding mechanisms (grant programs, low interest loans) might be needed to reduce the capital costs and provide net savings to livestock producers.

Research and Development – Additional research should be performed to identify the best technologies suited for energy development at Arizona dairies/feedlots. For at least one of the feedlot demonstration projects, investigate the potential of a combined manure digester and ethanol production plant. In these projects, the spent grain from the ethanol process would be used as feed for the cattle. Heat and electricity produced from the manure digester is used in the ethanol plant to reduce fossil-based energy use.

Related Policies/Programs in Place: None identified.

Types(s) of GHG Benefit(s):

- **CO_2:** Use of methane captured in manure digesters to generate electricity displaces fossil fuel use and associated CO_2.
- **CH_4:** Manure digesters collect and combust the CH_4 produced from anaerobic decomposition during manure storage.
- N_2O emissions from manure management are not likely to be affected by this policy option. N_2O emissions from fossil fuel-based electricity will be offset.
- **Black Carbon:** Use of methane captured in manure digesters to generate electricity displaces fossil fuel use and associated BC emissions.

Estimated GHG Savings and Costs per tCO_2e (for quantified actions):

- GHG potential in 2010, 2020: 2010 Dairies = 0.16 $MMtCO_2e$; 2020 Dairies = 0.49 $MMtCO_2e$; Feedlots 2010 = 0.0005 $MMtCO_2e$; 2020 Feedlots = 0.005 $MMtCO_2e$.
- Net Cost per tCO_2e: Dairies = $1; Feedlots = $580

Based on the high costs and low GHG reductions for feedlots, only the benefits and costs for dairies are included in the policy summary at the beginning of this document.

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** Data from the GHG inventory and forecast report on methane emissions and dairy/feedlot populations were used as the starting point. It is important to note that the TWG did not want to assume any growth in either the dairy or feedlot cattle populations in future years. Hence, they were kept at 2004 levels. Methane emissions at feedlots are much lower than those at dairies due to the differences in manure management and storage at these different operations. Consistent with the policy design, manure digesters are assumed to be implemented at dairies covering 25% of the state population by 2010. By 2020, 75% of the dairy cattle population is assumed to be covered. For feedlots, 5% of the feedlot cattle are covered in 2010 and 50% are covered by 2020.

  For each facility that installs a manure digester or other energy capture/utilization technology, it is assumed that 75% of the methane emissions are collected (due to inefficiencies in the manure collection process). This methane is converted to electricity using a heat rate of 17,100 Btu/kWh. The annual kWh produced were used to estimate both the costs offset (through avoided electricity consumption), as well as GHGs offset (from grid power). The 2010 grid power emission factor used was 1.607 lb CO_2e/kWh. For 2020, this value was 2.223 lb CO_2e/kWh (which factors in a higher level of coal-based power production in 2020). These values were taken from the AZ GHG Inventory & Forecast Report.

  The CO_2e reduction benefits were calculated as the sum of the methane emissions reduced, plus the GHG offset from grid-based power. Costs were estimated using data on capital costs from EPA's Methane to Markets report[1] and a recent dairy manure digester application in central California. These data indicate a range of capital costs from about $190 to $450 per head. An annual operating cost of $38/head was also estimated from the central California project.[2] An electricity offset cost of $0.04/kWh was also used. High and low annualized costs were estimated using the high and low estimates of capital costs. The reported costs for the policy are the mid-range of these estimates. A 15-year project life was assumed along with a 5% interest rate to determine the capital recovery factor.

- **Quantification Methods:** See discussion above.
- **Key Assumptions:** No further growth in dairy and feedlot operations in Arizona (data indicate nearly 5% annual growth in the dairy herd since 1990).

  Most applications of manure digesters in the U.S. have been conducted at dairies with liquid (slurry) manure management systems. For livestock operations that manage manure primarily in solid form, there could be major differences in energy technology

[1] http://www.methanetomarkets.org/resources/ag/docs/animalwaste_prof_final.pdf, accessed March 2006.
[2] Williams, Douglas, Valley Air Solutions, presentation "Joseph Gallo Farms Dairy Manure Digester", January 18, 2006.

selected (e.g., for solid manure, biomass gasification might be a better alternative). These different technology choices could carry higher or lower costs than those used here for anaerobic lagoon digesters combined with an engine and electricity generator. CCS believes that the range of costs considered in this analysis represents, on the low end, manure energy projects implemented for a group of farms (e.g., regional digesters/energy plants) to high end costs, where the digester/energy plant is implemented at a single facility.

Key Uncertainties:

The effects of the no-growth assumption above. This could lead to a significant underestimate of future benefits. The costs associated with anaerobic digester/energy plant application at Arizona dairies and their representativeness to the energy technology actually selected.

Ancillary Benefits and Costs, if applicable:

- Reduction of ammonia, VOC emissions, and odor.
- Reduction of fossil fuel-based energy consumption.
- Could enhance the value of manure through higher demand for manure overall and potentially higher quality of digested manure.

Feasibility Issues, if applicable:

- In the U.S., about 7% of greenhouse gas emissions are from agriculture, with the major source of agricultural emissions being nitrous oxide from agricultural soils. About 25% of agricultural emissions come from waste management activities and about 25% from enteric fermentation. We have a lot of interest in developing domestic energy sources, especially in rural areas where electricity is more difficult and expensive to obtain. We would like to focus on making some of these technologies more affordable (e.g., high initial cost of anaerobic digesters compared to other management methods).
- Need to identify methods for integrating this form of distributed power into the power grid in Arizona.
- Due to the current high costs and relatively low benefit associated with energy utilization at feedlots, the TWG recommends limiting this option to dairies only. For feedlots, the TWG recommended additional research and pilot projects to assess the future viability of energy recovery projects.

Level of Group Support:

Unanimous consent.

A-2 Biomass Feedstocks for Electricity or Steam Production

Policy Description:

Displace fossil fuel usage through the use of agricultural waste (e.g., orchard trimmings, and other crop residue) as a feedstock for electricity, steam, or space heat production.

Policy Design:

- **Goal levels:** Program goal of using 50% of available agricultural biomass residue for energy use by 2020.
- **Timing:** 20% of available biomass used by 2010, 50% by 2020.
- **Parties:** Arizona Department of Agriculture, Agricultural Cooperative Extension Offices, Arizona Department of Environmental Quality, Arizona Growers Association, and crop producers.
- **Other:** For the purposes of quantifying the costs and benefits of this option, biomass energy was assumed to be pelletized and used for commercial or residential space heating or steam production. The benefits were estimated by quantifying the amount of fossil fuel displaced (assumed to be natural gas).

Implementation Method(s):

Pilots and Demonstrations – Pilot projects on the use of different residues for energy production are needed.

Research and Development – Research is needed on techniques for collecting and processing crop residues, as well as markets for these materials.

Market-Based Mechanisms – Incentives (e.g., preferential tax rates) may be needed to spur the use of biomass energy.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO_2:** Savings occur as a result of displacing fossil fuel use in the production of electricity or steam.
- **CH_4:** Not applicable (savings only occur if it can be demonstrated that biomass combustion produces less methane than fossil-based combustion).
- **N_2O:** Not applicable (savings only occur if it can be demonstrated that biomass combustion produces less methane than fossil-based combustion).
- **HFC's, SFC's:** Not applicable.
- **Black Carbon:** Likely to be a reduction in BC emissions to the extent that coal-based combustion is offset (if electricity is generated from any of the biomass utilized).

Estimated GHG Savings and Costs per tCO_2e (for quantified actions):

- GHG potential in 2010, 2020: 0.05 $MMtCO_2e$ in 2010, 0.13 $MMtCO_2e$ in 2020
- Net Cost per tCO_2e: -$8

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** Harvested acres for corn grain, sorghum, barley, oats, winter wheat, and durum wheat, and orchards were obtained from USDA NASS[3]. Per acre crop residue yields for grain crops were taken from a joint study by the USDA and US DOE[4]. An estimate of biomass yields from orchard trimmings was taken from a report from the National Renewable Energy Laboratory[5]. Estimates of the energy content in kWh/ton for switchgrass pellets (used to estimate crop residue) were obtained from Resource Efficient Agricultural Production Canada[6]. The energy content for wood pellets was taken from a wood pellet brochure[7]. The delivered costs for biomass pellets were obtained from Resource Efficient Agricultural Production Canada[8]. A comparison of the biomass resources available using the above data to the Western Governors' Association's Clean and Diversified Energy Advisory Committee's (CDEAC) report on regional biomass resources[9] yielded very similar results (301,000 dry tons of residue compared to the CDEAC estimate of 317,000).
- **Quantification Methods:** Acreage data and the tons of crop residue (or orchard trimmings) per acre were used to estimate the total amount of available biomass from existing crops. Estimates of the energy content for switchgrass pellets (19.3 MMBtu/ton for crop residues) and wood pellets (16.4 MMBtu/ton for orchard trimmings) were used to estimate the total energy that could be generated using biomass pellets. The amount of CO_2e avoided by burning biomass instead of natural gas was estimated by subtracting the biomass emission factor (14.96 lbs CO_2e/MMBtu) from the residential natural gas emission factor (116.7 lbs CO_2e/MMBtu). No adjustments were made for the potential differences in efficiencies between the natural gas fired and biomass fired equipment.
- **Key Assumptions:** Crop acreage for grains was assumed to remain constant for 2005–2020 and orchard acreage was assumed to remain constant for 2002–2020. The energy content and pelletizing costs for Arizona crop residue were assumed to be the same as for an analysis of pelletized switchgrass conducted in Canada.

Key Uncertainties:

- **Benefits:** The values for crop residue yields are based on National values, and may differ for crops in Arizona. It is uncertain whether all types of AZ crop residues can be economically recovered for energy use (additional research needed). The energy content of Arizona crop residue may differ from that of switchgrass. Another uncertainty is the acreage of potential biomass crops in 2010 and 2020. The benefits are quantified as the amount of fossil fuel (natural gas) offset with biomass energy for space heating. Full

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[3] AZ State Agriculture Overview – 2005, http://www.nass.usda.gov/Statistics_by_State/Ag_Overview/AgOverview_AZ.pdf
[4] Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply, 2004, http://www.ethanolrfa.org/objects/documents/92/billion_ton_vision.pdf
[5] Lessons Learned from Existing Biomass Plants, NREL, 2000, http://www.nrel.gov/docs/fy00osti/26946.pdf
[6] Grass Biofuel Pellets, http://www.reap-canada.com/bio_and_climate_3_2.htm
[7] http://www.energycentre.info/pdf/dokumentarkiv/brochure_about_wood_pellets.pdf
[8] Grass Biofuel Pellets, http://www.reap-canada.com/bio_and_climate_3_2.htm
[9] 2005. WGA Clean and Diversified Energy Advisory Committee (CDEAC) Biomass Supply Report - http://www.westgov.org/wga/initiatives/cdeac/Biomass-supply.pdf.

life-cycle GHG benefits (i.e., embedded energy) for the production of pelletized biomass and natural gas were not incorporated into this analysis.

- Costs: The costs of production and transport of pellets made from crop residue and orchard trimmings may differ from that of switchgrass.

Ancillary Benefits and Costs, if applicable:

- Increased costs associated with collecting and transporting biomass.
- Increased emissions associated with collection and transport.
- Decrease in emissions in some cases – e.g., situations where open burning of residue is replaced by controlled combustion.

Feasibility Issues, if applicable:

None were identified.

Level of Group Support:

Unanimous consent.

A-3 Ethanol Production and Use

Policy Description:

Provide incentives for the production of ethanol from crops, agricultural waste, or other materials. Use of the ethanol will offset fossil fuel use (gasoline). Different incentive programs will be needed for crop (starch-based) ethanol production versus agricultural waste (cellulosic) ethanol production processes.

Policy Design:

- **Goal levels:** Three production goal options were assessed. The first involved production of enough ethanol to support the use of E10 (10% ethanol by volume in gasoline) year round in areas that currently use it during the winter season (Maricopa, northern Pinal, and Pima Counties). Year round use would more than double the current usage levels of ethanol in Arizona. The second option involved producing enough ethanol to support alignment with the New Mexico CCAG goal of 20% ethanol usage by volume in gasoline by 2012. The third option was alignment with the New Mexico CCAG goal of 40% ethanol by 2040.
- **Timing:** The timing for the first option is by 2010. This would require the production of 207 MMgal/yr. The second option is to be achieved by 2020, and it would require the production of 858 MMgal/yr at that time. The third option would require production of 3,450 MMgal/yr by 2050. Note: production from the new Pinal County facility (55 MMgal/yr capacity) is included in the forecasted goals.
- **Parties:** Arizona Department of Environmental Quality, Arizona Department of Agriculture, and various industries and industry associations which produce feedstock for ethanol production (growers, solid waste, forest products, etc.).

Implementation Method(s):

Pilots and Demonstrations – Incentives are needed to attract investment in commercial cellulosic ethanol production plants;

Research and Development – Additional research is needed to identify the availability of appropriate feedstocks for ethanol production. The new Pinal Energy Plant is expected to take up a significant fraction of the potential corn production in the state. Additional feedstocks for starch-based production are probably limited in AZ. Cellulosic feedstocks should be identified for commercial application;

Market-Based Mechanisms – This policy option focuses strictly on the production of ethanol for use in transportation. Programs are needed to assure sufficient in-state demand for ethanol (e.g. a renewable fuels standard). The demand-side issues are handled by the Transportation and Land Use TWG.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO_2:** CO_2 emissions are reduced by offsetting the use of petroleum-derived gasoline and diesel. Energy requirements of producing ethanol need to be compared to the energy requirements of producing gasoline to completely assess the CO_2 benefit. While both starch-based and cellulosic ethanol production processes produce GHG benefits, the benefits from cellulosic ethanol are much higher and were used to estimate the benefits for this option. See the discussion below.
- **Black Carbon:** Differences in BC emissions between gasoline and ethanol-blended gasoline are probably negligible.

Estimated GHG Savings and Costs per tCO_2e (for quantified actions):

Option 1:

- GHG potential in 2010, 2020: 0.49 $MMtCO_2e$; 0.64 $MMtCO_2e$.
- Net Cost per tCO_2e: $0

Option 2:

- GHG potential in 2020, 2050: 4.03 $MMtCO_2e$; 8.46 $MMtCO_2e$
- Net Cost per tCO_2e: $0

Option 3:

- GHG potential in 2050: 18.4 $MMtCO_2e$

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** Production volumes for each scenario in each year are based on forecasted gasoline consumption (from the Arizona Inventory & Forecast), current and planned ethanol production in the State, and the volume of gasoline to be offset in each year. Costs for all ethanol production are based on estimates for cellulosic technology[10] and do not include the costs for the new starch-based Pinal Energy Plant. Life-cycle emission CO_2e emission factors from a General Motors sponsored[11] were used to estimate the emission reductions associated with offsetting gasoline consumption with varying in-state production volumes. In this study, emission factors were developed using Argonne National Laboratory's (ANL) Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model. This study is included as an appendix to this report.
- **Quantification Methods:** Well-to-wheels CO_2e emission factors from a recent Argonne National Laboratory Study were used to estimate the benefits of offsetting conventional gasoline with starch-based ethanol (from the Pinal Energy Plant) and cellulosic ethanol for all incremental production needed to fulfill the policy goals. Well-to-wheels emission factors take into account the energy required to produce, process, and transport each fuel type (i.e., starting with the oil well for gasoline and the crop for starch-based

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[10] Charles Bensinger, Sunbelt Biofuels, personal communication with S. Roe, CCS. Costs based on cellulosic plants in the 7 to 11 MMgal/yr production range. Plants use either manure or municipal solid waste as feedstock. Plants are profitable at ethanol prices of $1.90/gal (current price is $2.70/gal). Costs to produce cellulosic ethanol range from $1.28 - $1.40/gal.

[11] *Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems– A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions*, General Motors, Argonne National Lab, and Air Improvement Resource, Inc., May 2005.

ethanol). These emission factors are output from ANL's GREET Model (all based on an average fuel economy of 21 mi/gal):

Reformulated gasoline = 552 g CO_2e/mi;

Corn (starch) ethanol = 451 g CO_2e/mi;

Cellulosic ethanol = 154 g CO_2e/mi.

As shown in these emission factors, use of corn (starch-based) ethanol results in a CO_2e reduction of about 18% relative to the use of reformulated gasoline. Cellulosic ethanol consumption results in a CO_2e reduction of about 72%. Although the TWG did not recommend that this policy should target only incentives to cellulosic ethanol production, benefits of this option were estimated assuming that additional ethanol production capacity in Arizona (beyond the Pinal Energy Plant) would come from cellulosic ethanol.

The costs to produce cellulosic ethanol were taken from recent analyses of a member of the New Mexico Climate Change Advisory Group.[18] Costs for the Pinal Energy Plant were not included in the assessment. Based on the current costs to produce cellulosic ethanol and the wholesale price of ethanol, these plants can be profitable (estimates are that a plant can be profitable at an ethanol price of $1.90/gallon, while the current wholesale price is around $2.70/gallon). Starch-based ethanol plants are being built or planned in many areas of the country due to these favorable economics (costs to produce starch-based ethanol were not identified). Due to the apparent profitability of either type of plant, a net zero cost is assumed for this option.

- Key Assumptions: These include: future ethanol production in Arizona will come from cellulosic ethanol plants; production volumes are set at one of the selected scenarios; current costs for cellulosic ethanol production are accurate and not expected to change considerably over the policy period (thru 2020); and current ethanol prices will not fall substantially to the point of making near-term cellulosic plants economically infeasible.

Key Uncertainties:

Representativeness of ANL's GREET model emission factors to starch-based and cellulosic ethanol production associated with Arizona-specific feedstocks and production facilities; future costs of cellulosic ethanol production (plants in the near future are likely to use enzymatic processes that have lower costs than today's acid hydrolysis technology).

Ancillary Benefits and Costs, if applicable:

- Gasoline-ethanol blends may increase or decrease emissions of some criteria and toxic air pollutants (decrease in aromatic hydrocarbons, such as benzene, toluene, and xylenes; increases in aldehydes, like formaldehyde and acetaldehyde).
- In-state job growth.
- Creates markets for current waste products (e.g., municipal solid waste, forestry and crop residues, and manure).

Feasibility Issues, if applicable:

The current wholesale ethanol pricing makes cellulosic ethanol plants very attractive. A sharp drop (e.g., below $1.90/gallon) will have a strong negative effect on private investment. Enzymatic processes for cellulosic ethanol production are expected to be commercially-available within the next 5 to 10 years.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous consent.

Members of the group expressed the need to reiterate that this option was not meant to favor cellulosic ethanol production exclusively, and that Arizona should further investigate additional production potential for starch-based ethanol.

A-7 Convert Agricultural Lands to Grasslands or Forests

Policy Description:

Increase carbon sequestration in agricultural land by converting marginal land used for annual crops to permanent cover (grassland or forests).

Policy Design:

No data were identified to assess the location and acreages of marginal agricultural land in AZ. Further, it is not clear whether significant marginal agricultural lands exist beyond those that are already included in the Federal Conservation Reserve Program (CRP). Finally, unless the marginal agricultural lands are located in higher elevation areas of the state that receive adequate precipitation, the incremental carbon benefits are likely to be negligible.

- **Goal levels:** Program goal of converting X acres of marginal agricultural land to grassland or forest. Information on the native land cover associated with these marginal lands (forest, grassland) or their location can also be factored in to the assessment of above and below ground carbon change.
- **Timing:** Acres of land converted to grassland or forest by 2010, 2020 and 2050.
- **Parties:** Not determined.
- **Other:**

Implementation Method(s):

Not determined.

Related Policies/Programs in Place:

Federal Conservation Reserve Program.

Types(s) of GHG Benefit(s):

- CO2: Loss of carbon to the atmosphere from tillage and fallow land is reduced by converting land to permanent cover. This increases soil carbon content. Above ground carbon stocks are increased by converting to cover with a greater ability to sequester carbon (i.e. higher biomass).

Estimated GHG Savings and Costs per tCO_2e (for quantified actions):

- GHG potential in 2010, 2020: Not quantified.
- Net Cost per tCO_2e: Not quantified

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** See discussion under Policy Description above.
- **Quantification Methods:**
- **Key Assumptions:**

Key Uncertainties:

None identified.

Ancillary Benefits and Costs, if applicable:

None identified.

Feasibility Issues, if applicable:

See discussion under Policy Description above.

Status of Group Approval:

Completed

Level of Group Support:

Minority

Members noted the lack of data to quantify benefits and costs for this option (i.e., availability of marginal agricultural lands in AZ that could be converted to native cover that were not already covered by the Conservation Reserve Program).

A-8 Reduce Permanent Conversion of Farm and Rangelands to Developed Uses

Policy Description:

Reduce the rate at which existing crop and rangelands are converted to developed uses. The carbon sequestered in soils and above-ground biomass is higher in crop and rangelands than in developed land uses.

Policy Design:

- **Goal levels:** Program goal of reducing the rate of crop and rangeland loss to 50% of the loss rate from 1982 to1997 by 2020.
- **Timing:** 20% reduction in loss rate by 2010, 50% by 2020.
- **Parties:** County Governments, non-government organizations (land trusts), and Arizona State Land Department.

Implementation Method(s):

Information and education; technical assistance; voluntary or negotiated agreements; funding mechanisms or incentives.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO_2:** Conservation of agricultural lands retains the ability of the land to sequester carbon in soil and biomass. Agricultural lands tend to hold more carbon than developed uses. These direct benefits were quantified below. Retention of agricultural lands also indirectly reduces CO_2 emissions by encouraging less suburban sprawl and the associated transportation-related emissions.

Estimated GHG Savings and Costs per tCO_2e (for quantified actions):

- GHG potential in 2010, 2020: 0.08 $MMtCO_2e$; 0.20 $MMtCO_2e$.
- Net Cost per tCO_2e: $65

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** The number of acres that moved from cropland, pasture, and rangeland categories to developed uses between 1982 and 1997 was obtained from the USDA Natural Resource Inventory (NRI). Agricultural land soil carbon data was taken from a study in *Soil Science* that compiled data for cultivated and uncultivated land with various soil types[12]. Estimates of soil carbon on Arizona rangeland was obtained from the STATSGO/SSURGO SOC database.

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[12] Mann, L.K. 1986. Changes in soil carbon storage after cultivation. Soil Science 142(5):279-288.

Costs for agricultural land can vary widely from as low as $200/acre in rural areas without significant water supply to as much as $100,000/acre in prime locations with high development potential.[13] Costs were estimated for this option using a cost of $2,000/acre for conservation easement. This cost represents the nationwide average determined by the American Farmland Trust.[14]

- **Quantification Methods:** The number of acres of cropland, pasture, and rangeland converted to developed uses between 1982 and 1997 was divided by 15 years to give the average number of acres lost each year. The number of acres to be saved in 2010 and 2020 were estimated by multiplying the average rate for 1982–1997 by 20% and 50%, respectively. The amount of CO_2 emissions savings were estimated by assuming that for each acre lost to development, 10,000 sq ft (0.23 acre) losses 100% of the soil carbon. The remainder of the acre losses 25% of soil carbon.
- **Key Assumptions:** Above-ground carbon stocks for agricultural lands and rangeland was assumed to be small compared to soil carbon. For each acre of land lost to development, 10,000 square feet is assumed to lose 100% of the soil carbon. This area represents the area in buildings, streets, and other structures that cover the soil. A loss of 25% of the soil carbon is assumed for the remainder of the acre.

Key Uncertainties:

The main areas of uncertainty are the existing soil carbon stocks and the change in soil carbon when land is developed.

Ancillary Benefits and Costs, if applicable:

- Transportation emissions may also be reduced by directing growth to more efficient locations.

Feasibility Issues, if applicable:

None identified.

Level of Group Support:

Unanimous consent.

[13] Bob Findling, The Nature Conservancy, personal communication with H. Lindquist, CCS, June, 2006.
[14] American Farmland Trust, A National View of Agricultural Easement Programs, http://www.aftresearch.org/PDRdatabase/NAPidx.htm.

A-9 Programs to Support Local Farming/Buy Local

Policy Description:

This option seeks to promote consumption of locally produced agricultural commodities, which would offset consumption of commodities transported from other states or countries. It includes the modification, enhancement, and further development of local farm programs employed in Arizona to reduce transport-related GHG emissions.

Policy Design:

- **Goal levels:** The object of expanding local farm programs and coordinating existing community programs is to increase consumption of agricultural products from sources within Arizona. In addition to the benefits of reducing fuel usage, transportation costs and air pollutant emissions, consuming locally grown foods will directly support Arizona producers, consumers, and retailers. This policy looks to increase consumption of Arizona grown commodities by 10%, thereby offsetting commodities transported from other states/countries by the same amount.
- **Timing:** While reducing greenhouse gases in Arizona and achieving a 10% increase in the consumption of local farm commodities, the expansion, coordination, development, and implementation of local farm programs requires financial support and "cause marketing" that will connect consumers to the value of sustaining Arizona's agricultural industry. To achieve the goal of this policy, implementation milestones are estimated at 5% by 2010 and another 5% by 2020 (total of 10% offset in 2020).
- **Parties:** Agricultural producers, industry, communities, government, and others in Arizona.

Implementation Method(s):

Information and education; technical assistance; codes and standards, including State government preferred purchases for local agricultural commodities; market-based mechanisms; research and development, including research into methods to measure and monitor in-state and local agricultural commodity purchases and imported commodities.

Related Policies/Programs in Place:

Community Supported Agriculture Farmers Markets, North American Farmer's Direct Marketing Association (NAFDMA), Farmers' Market Nutrition Program (FMNP), Arizona Grown Program, The 5-A-Day for Better Health Program, U-Pick Programs Greenhouse Production, and Agritainment Business.

Estimated GHG Savings and Costs per tCO_2e (for quantified actions):

- GHG potential in 2010, 2020: 0.01 $MMtCO_2e$, 0.02 $MMtCO_2e$
- Net Cost per tCO_2e: $6.

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** Estimates of harvested acres, crop yields, and crop value and production estimates for beef and dairy products were taken from Arizona Agricultural Statistics 2004. Estimates of state exports were obtained from the USDA Economic Research Service (ERS).[15] U.S. per capita consumption rates were obtained from the ERS Food Consumption (Per Capita) Data System.[16] Arizona population data were obtained from the Arizona Department of Economic Security.
- **Quantification Methods:** The amount of each crop produced in Arizona was estimated using harvested acres and estimates of crop yields per acre. The amount of each crop consumed in Arizona was estimated using U.S. per capita consumption rates and the Arizona population. State export values were reported for commodity class. These values were allocated to each crop based on the crop value for each individual crop compared to the total value for all crops in the commodity class. Export values were then converted from dollars to weight using an estimated price calculated from the crop production value and amount produced for each crop. The amount consumed and exported for each crop was then subtracted from the amount produced to determine how much of the crop was imported. For each imported crop, a likely state of origin was chosen (California for carrots, tomatoes, onions, grapes, eggs, and milk; Oklahoma for beef; Idaho for potatoes). The estimated amount of imports for each crop and the estimated round-trip mileage were then used to estimate ton-miles transported and CO_2 emissions. These calculations were repeated for 2010 and 2020 using population projections to estimate future consumption. Reductions were estimated by multiplying the 2010 emissions by 0.05 (representing 5% offset of imported food) and the 2020 emissions by 0.10 (10% offset).

  Costs were based on the estimated need for one additional full-time equivalent (FTE) employee employed by the state (e.g., Arizona Department of Agriculture) to implement the elements of this policy. Some of the elements of this policy could be incorporated into existing programs (e.g., Arizona Grown Program; see above). The total cost for this additional FTE is $75,000/year in 2006 dollars.
- **Key Assumptions:** Transportation emissions were estimated by assuming 23 tons of payload per truck, 6 truck miles per gallon of diesel fuel and 22.4 lb CO_2 per gallon of diesel fuel. To estimate miles traveled, food from California was assumed to travel from Fresno to Phoenix (600 miles), food from Oklahoma was assumed to travel from Oklahoma City to Phoenix (1,000 miles), and food from Idaho was assumed to travel from Boise to Phoenix (1,150 miles). These mileage estimates were then doubled, since it was assumed that each truck would return to its point of origin empty. The amount of food produced and exported is assumed to remain constant, while consumption is assumed to grow with population.

Key Uncertainties:

One uncertainty is the amount of food products leaving the State. State export data from ERS includes only foreign exports. These estimates do not include state-to-state exports. Also, these estimates do not take into account that a large portion of some crops may be shipped out of Arizona when they are in season, and imported into the State when they are

[15] State Export Data, http://www.ers.usda.gov/Data/StateExports/.
[16] Food Availability: Spreadsheets, http://www.ers.usda.gov/Data/FoodConsumption/FoodAvailSpreadsheets.htm.

not in season. The benefits were quantified at the state level. As such, they do not capture additional GHG benefits where local (e.g., community-level) production and consumption takes place (resulting in addition ton-mile reductions). The quantified benefits could also be conservatively low since the assumptions for out-of-state-produce were based on the nearest likely producer state. Many commodities come from much further away (including foreign countries) and can travel by more energy intensive methods (e.g., air transport). Finally, the assumed transport routes are a single trip from city of origin to Phoenix. Many commodities will make several trips prior to reaching their final point of consumption (e.g., for packaging, storage, processing, etc.). The overall impact of all of the assumptions is that the benefits are underestimated by a large amount.

Ancillary Benefits and Costs, if applicable:

- Reduction in criteria and toxic air pollutants.
- Collaboration of local farm programs with other food programs provides nutritional education and increases the consumption of healthy foods for all Arizonans.
- Educate adults and children, about Arizona agriculture and agriculture's impact on their lives.
- Support for local agricultural jobs.

Feasibility Issues, if applicable:

None identified. Much of this option involves a continuation and/or enhancement of existing programs.

Level of Group Support:

Supermajority.

Barriers to consensus (if less than unanimous consent):

A small minority of the TWG felt that the quantification showed that there was only a small potential for GHG benefits for this option. Some group members also felt that this option needed additional work in the development of implementation details and quantification of benefits and costs. CCAG members should be aware of the uncertainties described above and the conservative approach taken in the quantification of benefits. It should also be noted that the current policy design only calls for offsetting 10% of imported agricultural commodities by 2020. By offsetting 50% of these commodities, a reduction of 0.10 $MMtCO_2e$ could be achieved using the same quantification approach.

F-1 Forestland Protection from Developed Uses

Policy Description:

Reduce the rate at which existing forestlands and forest cover are cleared and converted to developed uses or damaged by development that reduces productivity.

Policy Design:

- **Goal levels:** Given the considerable carbon storage potential of forest and woodlands in Arizona, and the trend of loss of these vegetation types in the past two decades, we propose that policy initiatives decrease the conversion of forest and woodlands to urban and other developed uses to 50% or less of the rates of loss to these uses during the 1987–1997 period by 2010 and continuing through 2020.
- **Timing:** see discussion above.
- **Parties:** County governments, Arizona Department of Environmental Quality, and private non-profit land trusts. Forest protection accomplished through acquisition of conservation easements and fee title by public and private conservation organizations.

Implementation Methods:

Information and education; technical assistance; funding mechanisms; voluntary/negotiated agreements.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO_2:** Carbon savings occur when live carbon stocks (trees, shrubs, and some soil organic carbon) are protected from clearing and the associated decay or combustion of cleared biomass. Carbon losses are offset to some extent by the portion of harvested biomass that is converted to durable wood products (carbon storage in product use), and for that portion to be converted to renewable energy and displaces fossil energy use that otherwise would be used. Because conversion of forestland to developed land uses typically is permanent, replacement biomass does not grow back on the site to offset removals of live CH_4 biomass (i.e., to the levels that existed during forest use).
- **CH_4:** New research indicates that about 4% of the carbon storage benefits of live forests are offset by methane release. Methane can be released from land filled biomass under anaerobic conditions.
- **Black Carbon:** Emissions of black carbon (soot) result from combustion of biomass from open burning during land clearing, but the heating effect is likely to be offset by the large amount of organic material that is also emitted during biomass combustion.

Estimated GHG Savings and Costs per tCO_2e (for quantified actions):

- GHG potential in 2010, 2020: 0.31 $MMtCO_2e$/yr reduced in 2010 and 2020.

- Net Cost per tCO_2e: $17

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** The number of acres that were designated from forested land and rangeland to developed uses between 1982 and 1997 was obtained from the USDA Natural Resource Inventory (NRI). Based on the comparison of rangeland acreage from NRI and pinyon-juniper acreage from USDA Forest Service, it was determined that roughly 38% of rangeland is pinyon-juniper. For the purposes of this analysis, pinyon-juniper is considered forested land. Forest carbon stock per acre data values were calculated from 2003 USDA Forest Service carbon stock and acreage data.[17] Cost data for conservation easements on forested lands was obtained from the New Mexico Forest Legacy Program and The Nature Conservancy.[18] [19]

- **Quantification Methods:** The annual rate of loss from the NRI data was determined to be 7,400 acres/yr (combined forest and rangeland based on loss rates from 1982–1997). The rangeland acreage was adjusted to reflect the amount of pinyon-juniper forest on these lands (38% of rangeland in the NRI was estimated to be pinyon-juniper forest). Reducing the loss rate by 50% yields 3,700 acres/yr protected. Assumptions regarding carbon losses due to development are: for each acre lost to development, 10,000 sq ft (0.23 acre) looses 100% of soil carbon; the remainder of that acre loses 25% of soil carbon; 90% of above ground carbon is lost. The number of acres saved per year was multiplied by the loss of carbon on these acres to estimated carbon savings. Carbon savings were then converted to CO_2e.

  Costs were estimated as the midpoint of the high and low costs for identified conservation easements on forested lands in the southwest. The low cost was $720/acre for an easement; the high cost was $3,200 ($4,000/acre appraised land value and assuming 80% of land value for easement).

- **Key Assumptions:** Some rangeland carbon estimates are not currently included in forest carbon estimates due to data limitations; however, "Nonstocked" and "Pinyon-Juniper" forest stands as defined by FIA include many lands classified as "Rangeland" by NRI. Forecasted carbon stock measurements from 2002 to 2020 are based on extrapolations of past trends from 1982 to 1997 and assume a static continuation of all land cover and land use dynamics during that period. Implementation mechanisms are assumed to be "growth neutral" to avoid offsetting development impact, i.e., land protection does not result in land clearing in other areas (also referred to as "leakage"). Cost savings from avoided land clearing costs may be contingent on regulatory acceptance of alternative land development approaches, such as conservation design or cluster development.

Key Uncertainties:

- **Benefits:** The rate at which live biomass stocks would have declined beyond business as usual due to forest health and forest fire risks may be significant. The rate of offsetting development effects from land protection may be sensitive to the design of policy implementation tools.

- **Costs:** Regulatory acceptance of alternative development approaches by local governing bodies may affect potential cost savings of avoided land clearing costs.

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[17] Jim Smith, USDA Forest Service, personal communication with S. Roe, CCS.
[18] Bob Sivinski, NM Forest Legacy Program, personal communication with H. Lindquist, CCS, June, 2006.
[19] Bob Findling, The Nature Conservancy, personal communication with H. Lindquist, CCS, June, 2006.

Ancillary Benefits and Costs, if applicable:

- Protection of working lands for sustainable wood products use, recreation, and cultural and natural heritage.
- Environmental asset protection, including watersheds, wildlife, and air quality.
- Reduced costs of infrastructure and services for dispersed or low density development.
- Reduced transportation emissions from increased location efficiency.
- Certain biomass combustion technologies may result in significant air pollution.

Feasibility Issues, if applicable:

None identified.

Level of Group Support:

Unanimous consent.

F-2 Reforestation/Restoration of Forestland

Policy Description:

Expand forest cover (and associated carbon stocks) by regenerating or establishing forests in areas with little or no forest cover at present.

Policy Design:

- **Goal levels:** 430,000 acres of forestland impacted by wildfire restored to stocking rates of 47 tons of above ground biomass per acre (on average depending on forest type). Explore potential for additional benefits in restoring forests impacted by insect damage.
- **Timing:** 430,000 acres of forestland regenerated/established from 2008 to 2020, including approximately 70,000 acres regenerated/established by 2010 and 360,000 acres between 2010 and 2020. Average of 33,000 acres/year.
- **Parties:** USFS, AZ Forestry Division, Universities, City/County Governments, private industry.

Implementation Method(s):

Research and Development – need to identify forest areas that are best suited for restoration efforts; additional research needed to identify the potential for restoring areas impacted by insects/disease.

Funding Mechanisms - Additional work needed to identify funding sources.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO_2:** Carbon savings occur when forest carbon stocks (trees, shrubs, and soil organic carbon) are established and sustained above and beyond existing levels.
- **CH_4:** New research indicates that about 4% of the carbon storage benefits of live forests are offset by methane release.

Estimated GHG Savings and Costs per tCO_2e (for quantified actions):

- GHG reduction potential in 2010, 2020: 0.02 $MMtCO_2e$/yr in 2010; 0.09 $MMtCO_2e$/yr in 2020.
- Net Cost per tCO_2e: $44.

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** See footnotes to Option F1 for common references used to estimate carbon densities on Arizona forestlands [carbon stocks and above ground carbon densities are derived from the Forest Inventory Analysis (FIA) volumetric measurements conducted on a 5-year cycle by the USFS]. Acres burned in Arizona between 2000 and

2005 were obtained from USFS[20]. The total acres burned were used as the basis for the acreage to be reforested. A map of these areas is provided below.

- **Quantification Methods:** Reforestation of 5% of the burned areas was assumed for the 2008–2010 period. Another 25% of the burned areas was assumed to be reforested within the 2010–2020 timeframe. The amount of carbon to be sequestered on these lands was determined using the average above-ground carbon stocking for Arizona forestlands based on the Arizona Inventory & Forecast. The length of time for each restored stand to reach maturity was assumed to be 50 years. It was further assumed that without restoration, it would take 100 years for each stand to reach maturity. Cost data for reforestation projects were taken from a survey conducted by the Interstate Compact Mining Commission (relative to restoring coal mining lands).[21] These data suggest reforestation costs could range from $50 to $250 per acre. Due to the relative lack of Arizona-specific data and the years represented by the cost data, the high end of this range was used to provide a conservative estimate of program costs.
- **Key Assumptions:** Rates of forest regeneration (i.e., 2% annual biomass replacement in restored areas; 1% annual replacement without restoration).

Key Uncertainties:

- **Benefits:** The rate at which live biomass is regenerated on restored lands versus lands that do not receive any restoration treatment.
- **Costs:** The representativeness of the cost/acre data in the survey by Conrad[5]. The high end of the cost range was used in this analysis.

Ancillary Benefits and Costs, if applicable:

Restoration of forest ecosystems; watershed protection.

Feasibility Issues, if applicable:

CCS also received data on forested acres impacted by insect damage and disease. Additional GHG benefits could potentially be achieved through restoration efforts on these lands. Over 500,000 acres were impacted by insects and disease by 2002.[22] The TWG did not have sufficient time to explore the potential for restoring these insect-damaged areas.

Level of Group Support:

Unanimous consent.

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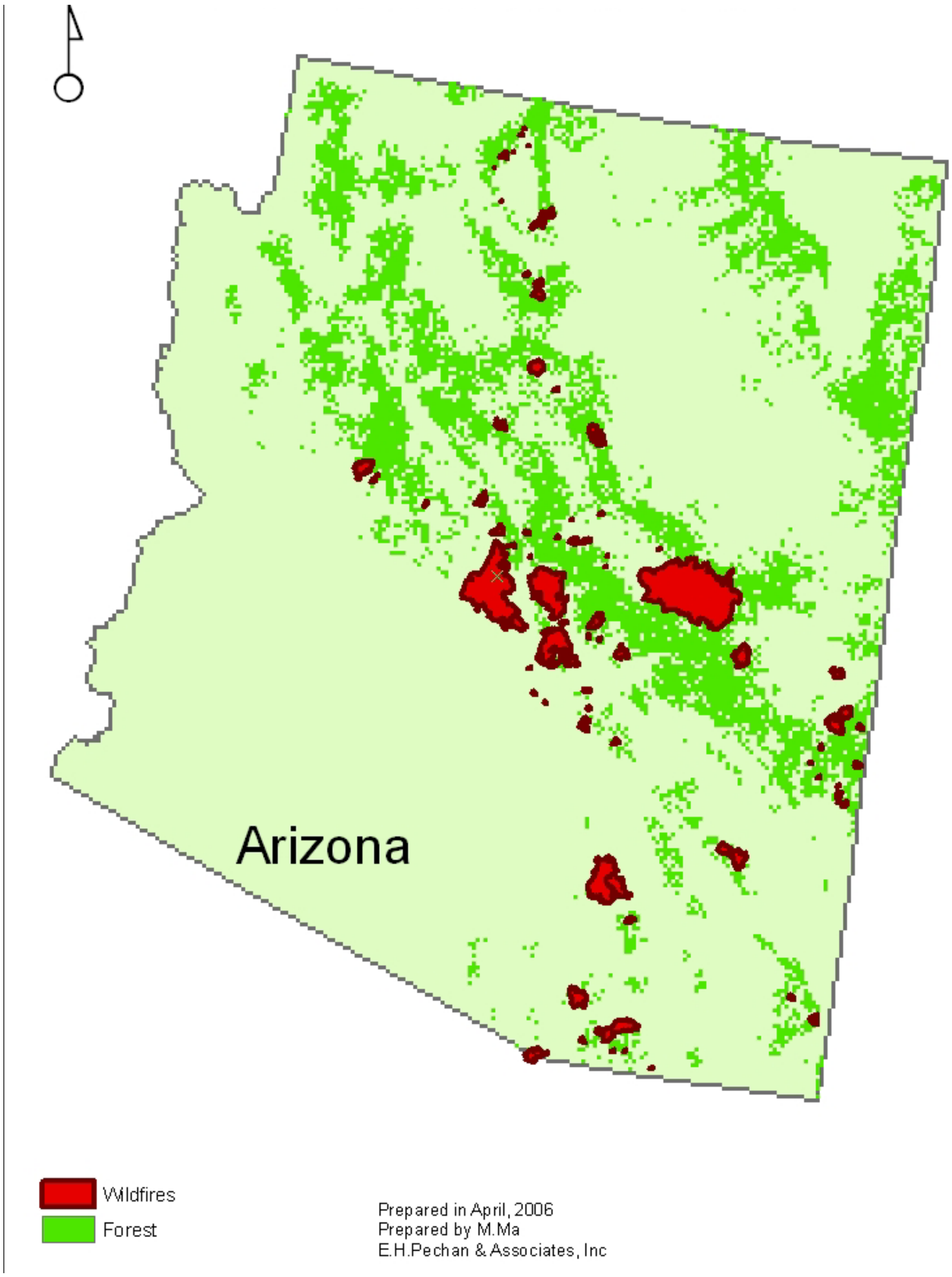
[20] Fire Perimeter data from D. Ryerson USFS; http://www.fs.fed.us/r3/gis/az_data.shtml.

[21] Conrad, G. Summary Report On State Reforestation and Tree Planting Statistics, Interstate Compact Mining Commission, http://www.mcrcc.osmre.gov/PDF/Forums/Reforestation/Session%201/1-4.pdf, date unknown.

[22] http://www.fs.fed.us/projects/hfi/docs/fact-sheet-arizona.pdf.

Figure 1. Arizona Wildfires, 2000-2005



F-3a Forest Ecosystem Management – Residential Lands

Policy Description:

Manage sustainable thinning or biomass reduction from residential forestlands (intended to address fire and forest health issues) so that harvested biomass is directed to wood products and renewable energy instead of open burning or decay. This option is directed at forestlands bordering residential areas (the wildland-urban interface or WUI). Option F-3b is directed at forests in non-WUI areas.

Policy Design:

- **Goal levels:** Wildfire and other threats to forest health and sustainability, and community safety have led to a number of initiatives within the state of Arizona to reduce biomass in residential forests and woodlands. Most of these efforts include some emphasis on utilizing the extracted woody biomass for wood products and/or energy production, rather than eliminating these materials through open burning, or storage or decay off site. Although this is an existing or potential objective for many restoration and biomass treatments on these lands, a greater emphasis and focus on wood products and/or energy production, through appropriate mechanisms, incentives, etc., is recommended. In particular, a reasonable goal of utilizing 50% or more of biomass extracted from residential lands for wood products and/or energy production is recommended to be achieved by 2010 and continuing through 2020. We also recommend that current and planned fuels treatments in Arizona be accelerated, so that all high priority areas (e.g., in wildand-urban interface) are treated by 2015. We further recommend that forest management practices and policies aimed at GHG reduction and carbon sequestration be reviewed by and coordinated with the Governor's Forest Health Oversight Council and Forest Health Advisory Council. It is quite likely that some policies already recommended by these councils, or may be recommended by the councils, are complementary and supportive of GHG reduction and carbon sequestration goals, while also promoting forest and ecosystem health and public safety. One of the key initiatives of the Forest Health Councils is a plan called "Sustainable Forests, Economies and Communities: A Statewide Strategy for Arizona Forests". This plan calls for, among other things, spatial database development and hazard assessment, and prioritized treatments.
- **Timing:** See text above.
- **Parties:** USFS, AZ Forestry Division, City/County Governments, and private industry.
- **Other:** For the purposes of estimating GHG benefits and costs, biomass is assumed to be utilized for the production of commercial steam/space heat or residential space heat. As stated above, other end uses (electricity generation, liquid fuels, durable wood products) should also be targeted by this policy.

Implementation Method(s):

Funding Mechanisms – Provide tax incentives to reduce the capital costs of biomass energy production, including electricity generation and heating of residences and public buildings; establish utility "Buyback Rates" for biomass derived energy where utilities offer a standard rate for which they purchase biomass generated energy (electricity and/or heat); and expand/develop renewable energy tax credits to develop new incentives for smaller distributed biomass generation.

Codes and Standards – Increase efficiency standards for wood burning equipment and appliances (e.g., wood burning furnaces and stoves). Develop or expand existing net-metering regulations to enable smaller projects to net-meter at retail energy rates.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO_2:** Carbon savings occur when live and dead carbon stocks (trees, shrubs) that otherwise would decay or burn in the forest, or be left for decay and or open burning following harvest, are harvested and converted to: 1) durable wood products that store carbon; 2) to low embedded energy wood building materials that substitute for high embedded energy conventional building materials (steel and concrete); or 3) to renewable energy that displaces fossil energy use. Sustainable management ensures that replacement biomass grows back to the maximum extent on thinned sites to offset removals of live biomass. Only the benefits associated 3) above have been quantified.
- **CH_4:** New research indicates that about 4% of the carbon storage benefits of live forests are offset by methane release. Methane can be released from land filled biomass under anaerobic conditions.
- **Black Carbon:** Emissions of black carbon (soot) result from combustion of biomass from open burning of land clearing, but the heating effect may be offset by the large emissions of organic material associated with biomass combustion.

Estimated GHG Savings and Costs per tCO_2e (for quantified actions):

- GHG potential in 2010, 2020: Approximately 0.46 $MMtCO_2e$/yr in both 2010 and 2020. Assumes that all biomass from mechanical treatments is diverted to energy use (displacing natural gas) and that 50% of all biomass treated by fire is diverted to energy use.
- Net Cost per tCO_2e: -$21 (based solely on displacement of natural gas; does not account for capital and annual costs associated with new biomass fired equipment.)

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** CCS obtained data on both mechanical and fire treatments conducted in Arizona from 2001 to 2006.[23] These data contained information on treatments that had occurred on both wildland-urban interface (WUI) lands and non-WUI lands. The WUI lands are those considered to be residential areas applicable to this option. The average acres treated during these years was used as the starting point for analysis. A map is provided below, which has county-level information (highest level of geographic resolution that the USFS would provide) on the total number of areas treated from 2001 to 2006, population centers, interstates, rail, transmission lines, and the small number of biomass plants currently operating in Arizona. The average carbon stocking on Arizona forestlands was taken from the USFS data that underlie the AZ Inventory &

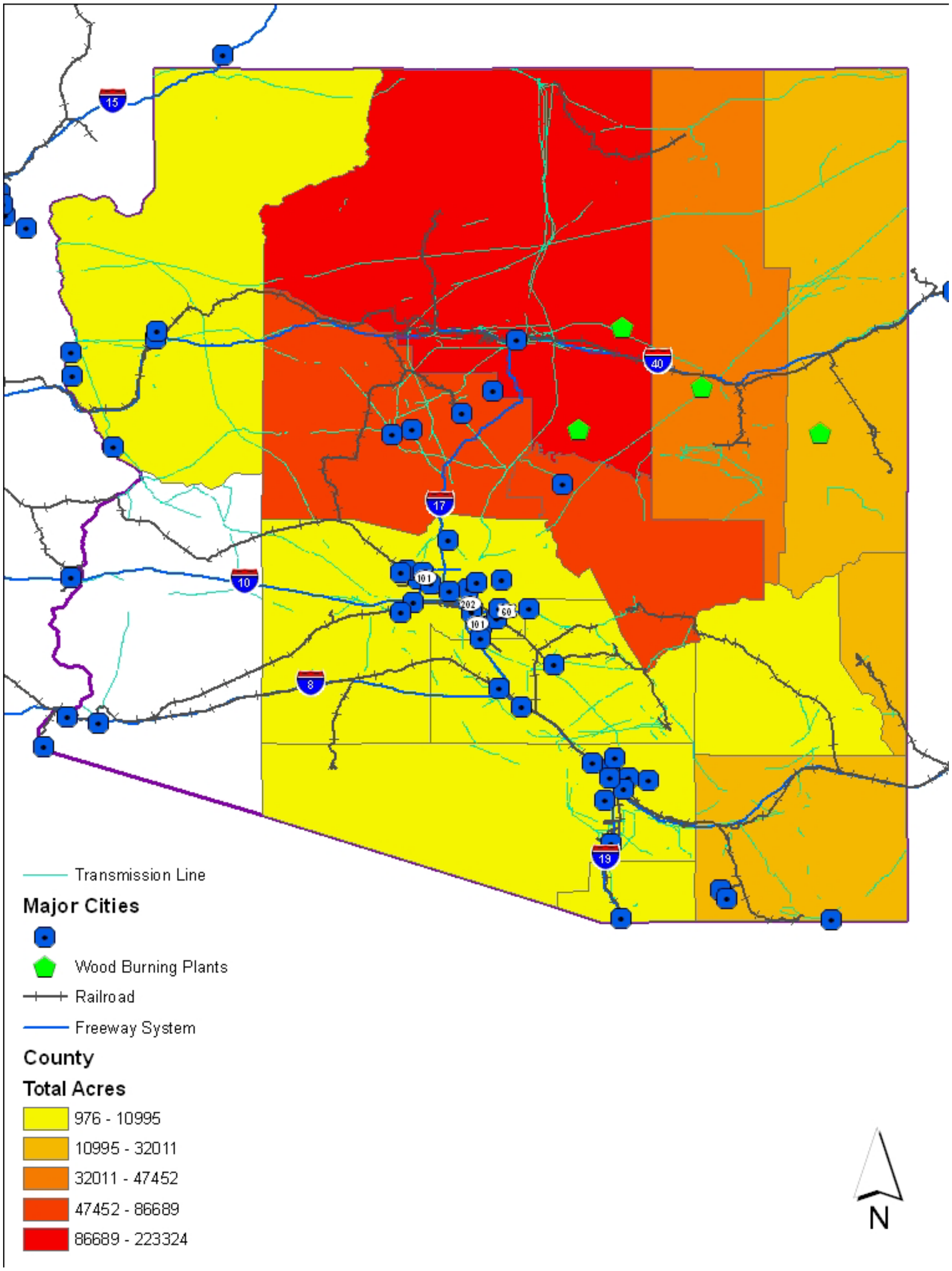
[23] J. Roland, USFS, email communication with S. Roe, CCS, 4/26/06. Data from the National Fire Plan Operations and Reporting System (NFPORS) database.

Forecast (i.e., USFS FIA). Estimates of the fraction of biomass to be removed in WUI and non-WUI areas was taken from an assessment by a researcher at Colorado State University.[24] A reduction in basal area of 42% associated with an "Intermediate Restoration Level" was selected for WUI lands. The reduction in basal area was assumed to be representative of a reduction in biomass density.

- Quantification Methods: The amount of biomass removed was then calculated by multiplying the annual acres treated by the above ground carbon density and the treatment fraction (0.42). CCS assumed that all of the biomass from mechanically treated areas would be diverted to energy use (space heat), while biomass from 50% of the fire treated acreage would be diverted. The heat content associated with the diverted biomass was then used to estimate the equivalent amount of natural gas offset (with no adjustment for potential differences in energy efficiency). Emissions from this offset natural gas were quantified as the benefit of this option. No effort was made to quantify the embedded energy (and CO_2e) associated with biomass diversion (neither were the life-cycle emissions associated with natural gas production and delivery investigated).
- Key Assumptions: Historical treatment areas are representative of future treatment programs. The average Arizona forest carbon density is representative of areas requiring treatment (areas requiring treatment could be stocked at levels higher than the State average). Historical treatment levels selected for analysis are representative of those to be achieved in future practice.

[24] Brett Dickson, CO State Univ.; Data on forest restoration levels provided to George Koch of the AZ AF TWG on 4/05/06; "Intermediate Restoration" level of treatment selected for WUI areas; reduction in basal area assumed to be representative in reduction of above-ground biomass.

Figure 2. County-level 2001-2006 AZ Fire Treatment Acreage



Key Uncertainties:

- **Benefits:** These initial estimates only account for utilization of the biomass as an energy source. Some fraction of this biomass could also find its way into merchantable timber. The benefits of this route of sequestration were not quantified. The market demand for new supplies of wood products and renewable energy is dynamic and not likely to fully absorb all new supply sources without offsetting decreases in other sources, unless there is support from policies that expand the market and, potentially, establish preferential treatment of these products in comparison to conventional supplies. The rate of biomass replacement growth in thinned stands could be less than full due to ecological barriers and forest health issues. Finally, the benefits associated with the lower risk of wildfire (i.e., associated carbon losses) are not quantified here, since these benefits are tied to forest treatments and this policy option is focused solely on the beneficial use of biomass energy from these treatments.

- Costs: As noted above, costs are based solely on displacement of natural gas. Capital and annual costs associated with new biomass fired equipment (e.g., municipal boilers or residential pellet stoves) are not captured in this assessment. Future cost reductions for wood product development and biomass energy recapture technologies are likely to fall with market expansion and "learning by doing" but are difficult to estimate at this time.

Ancillary Benefits and Costs, if applicable:

- Protection of residential and or municipal lands from fire risk.
- Expansion of markets for industrial producers of sustainable wood products and renewable energy use. Creation of Arizona jobs in the associated forestry management industries.
- Environmental asset protection, including watersheds, wildlife, and air quality.

Feasibility Issues, if applicable:

None identified.

Level of Group Support:

Unanimous consent.

F-3b Forest Ecosystem Management – Other Lands

Policy Description:

Increase sustainable thinning of biomass from forests and direct the harvested wood and wood waste to wood products and renewable energy. This option is directed at forests in non-WUI areas.

Policy Design:

- **Goal levels:**

  Scenario 1:

  Wildfire and other threats to forest health and sustainability have led to a number of initiatives within the state of Arizona to reduce biomass in forests and woodlands. Many of these efforts include some emphasis on utilizing the extracted woody biomass for wood products and/or energy production, rather than eliminating these materials through open burning, or storage or decay off site. Although this is an existing objective or potential objective for many restoration and biomass treatments on these lands, a greater emphasis and focus on wood products and/or energy production, through appropriate mechanisms, incentives, etc., is recommended. In particular, a reasonable goal of utilizing 50% or more of biomass extracted for wood products and/or energy production is recommended. We also recommend that current and planned fuels treatments in Arizona be accelerated, so that all high priority areas (e.g., in valuable watersheds and habitats) are treated by 2015 and continue through 2020.

  We further recommend that forest management practices and policies aimed at GHG reduction and carbon sequestration be reviewed by, and coordinated with, the Governor's Forest Health Oversight Council and Forest Health Advisory Council. It is likely that some policies already recommended by these councils, or may be recommended by the councils, are complementary and supportive of GHG reduction and carbon sequestration goals, while also promoting forest and ecosystem health and public safety. One of the key initiatives of the Forest Health Councils is a plan called "Sustainable Forests, Economies and Communities: A Statewide Strategy for Arizona Forests." This plan calls for spatial database development and hazard assessment, and prioritized treatments, among other things. This strategic plan is still in draft form as of writing this report. It would be useful to coordinate objectives and strategies of various forest and woodland policy options from the CCAG with this plan.

  Scenario 2:

  Accelerated restoration levels are anticipated as economic utilization activity increases demand for small diameter timber and woody biomass and decreases amounts paid for restoration/fuel reduction treatments through "service contracts" and actually results in land managers being paid for material removed through, for example, "timber sales" under current conditions approximately 52,800 acres of U.S. Forest Service land was projected to be treated by forest thinning in 2005, with 195,700 CCF of timber 5" dbh or greater removed and 229,200 tons of residue generated;

Timing of implementation: An average of 53,700 acres of U.S. Forest Service land on 6 national forests are proposed to be treated per year by thinning from 2005 through 2015, with an annual average of 192,500 CCF of timber over 5" dbh removed and 248,800 tons of residue generated, under current conditions. The acreage used to estimate benefits were taken from historical USFS treatment data (see data sources for F-3a above). For non-WUI areas, the acreage used was slightly lower than the initial policy design noted above. Annual acres treated from 2008 through 2020 are approximately 45,000.

Other: Current emphasis is on the wildland/urban interface zones throughout the State where communities and infrastructure are threatened by destructive wildfire, most have developed "Community Wildfire Protection Plans"; AZ Forest Health Oversight/Advisory Councils are developing a proposal – "Sustainable Forests, Economies and Communities: A Statewide Strategy for Arizona Forests" that will prioritize treatments statewide; focus mostly on ponderosa pine forests, but pinyon-juniper woodland treatments also needed.

- **Timing of implementation:** See discussion above.
- **Parties:** US Forest Service; AZ State Land Department.; DOI; Tribal lands; fire department & fire district fuel management crews; private landowners; local community-based groups – AZ Sustainable Forest Partnership, Greater Flagstaff Forests Partnership, Prescott Area Wildland/Urban Interface Commission, etc.
- **Other:** For the purposes of estimating GHG benefits and costs, biomass is assumed to be utilized for the production of commercial steam/space heat or residential space heat. As stated above, other end uses (electricity generation, liquid fuels, durable wood products) should also be targeted by this policy.

Implementation Method(s):

See Option F-3a.

Related Policies/Programs in Place:

None identified.

Types(s) of GHG Benefit(s):

- **CO_2:** Carbon savings occur when live and dead carbon stocks (trees, shrubs) that otherwise would decay or burn in the forest are harvested and converted to: 1) durable wood products that store carbon; 2) low embedded energy wood building materials that substitute for high embedded energy conventional building materials (steel and concrete); or 3) renewable energy that displaces fossil energy use. Sustainable management ensures that replacement biomass grows back to the maximum extent on thinned sites to offset removals of live biomass. Only the benefits associated with number 3 above have been quantified.
- **CH_4:** New research indicates that about 4% of the carbon storage benefit of live forests is offset by methane release. Methane can be released from land filled biomass under anaerobic conditions.
- **Black Carbon:** Emissions of black carbon (soot) result from combustion of woody biomass from open burning of land clearing, but the heating effect is likely to be offset by the cooling from the large amount of organic material emitted from biomass combustion.

Estimated GHG Savings and Costs per tCO_2e (for quantified actions):

- GHG potential in 2010, 2020: 0.21 $MMtCO_2e$/yr in both years (assumed constant treatment acreage)
- Net Cost per tCO_2e in 2010, 2020: -$21 (accounts for the costs associated with offsetting natural gas; does not include costs associated with the purchase of new biomass-fired equipment)

Data Sources, Methods, and Assumptions (for quantified actions):

- Data Sources: See discussion under F-3a above for a description of the data sources used. For non-WUI areas, the treatment level was assumed to be the "Fuels Reduction" level of restoration from the same source cited under F-3a. This led to a 21% reduction in biomass (and carbon) density on the treated acres.
- Quantification Methods: See the discussion under F-3a. The same approach was applied for non-WUI lands using a different level of treatment (21% reduction) as mentioned above.
- Key Assumptions: See Option F-3a.

Key Uncertainties:

- Benefits: The market demand for new supplies of wood products and renewable energy is dynamic and not likely to fully absorb all new supply sources, unless there is support from policies that expand the market and, potentially, establish preferential treatment of these products in comparison to conventional supplies. The rate of biomass replacement growth in thinned stands could be less than full due to ecological barriers and forest health issues. The benefits associated with the lower risk of wildfire (i.e., associated carbon losses) are not quantified here, since these benefits are tied to forest treatments and this policy option is focused solely on the beneficial use of biomass energy from these treatments.
- Costs: Future production cost reductions for wood product development and biomass energy recapture technologies are likely to fall with market expansion and "learning by doing" but are difficult to estimate at this time.

Ancillary Benefits and Costs, if applicable:

- Protection of working lands and associated industries for sustainable wood products use, recreation, and cultural and natural heritage.
- Expansion of markets for industrial producers of sustainable wood products and renewable energy use. Creation of Arizona jobs in the associated forestry management industries.
- Environmental asset protection, including watersheds, wildlife, and air quality.

Feasibility Issues, if applicable:

None identified.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous consent.

F-4 Improved Commercialization of Biomass Combustion, Gasification and Combined Cycle

Policy Description:

Accelerate the rate of technology development and market deployment of biomass combustion, gasification and combined cycle (BGCC) technologies.

Policy Design:

- **Goal levels:** 10 megawatts of biomass energy between 2006 and 2010, and an additional 25 megawatts between 2010 and 2020 (or equivalent amount of new biomass thermal energy).
- **Timing:** See above.
- **Parties:** Western Energy Resources (Eager); Renergy Systems (Snowflake); Northern Arizona University (Flagstaff); Camp Navajo/Volunteer Mountain Industrial Park (Bellemont); Forest Energy (Snowflake & Bellemont); Arizona Public Service, APS Energy Services; Salt River Project; Tucson Electric Power; and Rural Electric Cooperatives.
- **Other:** Technology improvements required to reduce emissions and improve efficiency of direct combustion; development of full scale commercial gasification systems needed; improved efficiencies for alcohol production from cellulose needed; and appropriate technologies to efficiently remove and transport biomass from forests need to be in place

Implementation Method(s):

Funding mechanisms and or incentives [USDA/DOE Biomass Initiative RFP; private investment; surcharges on Renewable Energy Standard & Tariff (RES, formerly EPS)], voluntary and or negotiated agreements [power purchase agreement; stewardship contracts to assure supply of biomass], codes and standards [Environmental Portfolio Standard revisions, proposed as RES], market-based mechanisms [green tags & RES credits], pilots and demonstrations [gasification systems; 3 MW ChipTek Unit of APS; Western Energy Resources; Renergy], research and development [NAU systems].

Related Policies/Programs in place:

USDA/DOE Biomass Initiative; RES proposals approved.

Types(s) of GHG Benefit(s):

- **CO_2:** Carbon savings occur when biomass energy combustion processes are converted from conventional technology to new technologies with greater thermal efficiency and reduced emissions with lower pollution outputs. New conversion technologies also may expand the use of available biomass supplies that substitute biomass energy for conventional fossil fuels. Increased efficiency and reduced emissions from burning/gasifying biomass in plants rather than “slash burning” in the forest as currently done. There will be significant reductions in CO_2 released from wildfire combustion of forest biomass when thinning treatments restore forest health and reduce the occurrence, areal? extent and intensity of wildfires; needs to be offset with contributions from increased prescribed burning necessary to maintain forest health.

- **CH_4:** New research indicates that about 4% of the carbon storage benefits of live forests are offset by methane release. Methane can be released from land-filled biomass under anaerobic conditions.
- **Black Carbon:** Emissions of black carbon (soot) result from combustion of woody biomass from open burning of land clearing, but the heating effect is likely to be offset by the cooling effects of the large amount of organic material emitted during biomass combustion.

Estimated GHG Savings and Costs Per tCO_2e (for quantified actions):

- GHG potential in 2010, 2020: Not quantified (forest biomass energy currently quantified under Options F-3a and F-3b.
- Net Cost per tCO_2e in 2010, 2020: Not quantified.

Data Sources, Methods, and Assumptions (for quantified actions):

- **Data Sources:** Steve Gatewood, AF TWG, provided the following data on the estimated costs and criteria pollutant production at biomass gasification facilities planned or proposed for application in Arizona.

  The existing 3MW Eager WER/APS plant consumes 110 tons/day of 40% moisture biomass, with approx. 46 tpy PM10, 52 tpy PM, 95 tpy CO, 4 tpy SOX, 35 tpy NOX & 6 tpy VOC; cost unknown;

  The ChipTek 3MW plant (not online yet – may go to NAU) consumes ~100 tons/day of 20% moisture chips, with approximately 45 tpy PM10, 52 tpy PM, 94 tpy CO, 4 tpy SOX & 35 tpy NOX; cost is about $7.8M;

  The proposed/permitted 24MW Renergy Snowflake plant would consume 480 tons/day of 50% moisture biomass, with approx. 23 tpy PM10, 252 tpy CO, 156 tpy SOX, 205 tpy NOX & 22 tpy VOC; cost is unknown;

  A 10MW plant proposed for Snowflake that might be replaced by the above 24 MW would use 295 tons/day of 38% moisture biomass, with 44 tpy PM10, 58 tpy CO, 11 tpy SOX, 57 tpy NOX & 8 tpy VOC; cost unknown;

  A 10MW gasification system proposed for NAU would use 248 tons/day of 40% moisture biomass, with unknown emissions; cost would be ~ $15M.

- **Quantification Methods:** The costs and benefits of this option were not quantified due to the overlap in biomass energy resource consumption with F-3a and F-3b. The TWG feels that this option supporting advancement of biomass gasification/combined cycle technology could produce even better GHG benefits than those shown for F-3a and F-3b.
- **Key Assumptions:** None.

Key Uncertainties:

- **Benefits:** The market demand for new supplies of renewable energy is dynamic and not likely to fully absorb all new supply sources without offsetting decreases in other sources, unless there is support from policies that expand the market and, potentially, establish preferential treatment of these products in comparison to conventional supplies.

- **Costs:** Future production cost reductions for biomass energy recapture technologies is likely to fall with market expansion and “learning by doing” but are difficult to estimate at this time.

Ancillary Benefits and Costs, if applicable:

- Criteria air pollution levels are lower with advanced technology. Gasification reduces emissions below the levels emitted via direct combustion.
- Alcohol production can reduce emissions of GHGs by offsetting gasoline use.
- Expanded biomass energy use also expands rural biomass industries.
- Eliminates open burning of slash–reduced smoke impacts and emissions and scarification of soils with resulting exotic species invasion.
- Significant reductions in emissions and pollutants through controlled combustion or gasification compared to open burning of slash or large wildfire releases.
- Criteria air pollution levels are lower with advanced technology than conventional biomass technology. Emission levels might not be as low as some conventional fossil fuel technologies (e.g., natural gas combustion technologies).
- Expanded biomass energy use also expands rural biomass industries.

Feasibility Issues, if applicable:

None identified.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous consent.

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- Expanded biomass energy use also expands rural biomass industries.

Feasibility Issues, if applicable:

None identified.

Status of Group Approval:

Completed.

Level of Group Support:

Unanimous consent.